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THE FERTILIZER NEEDS OF THE UNITED STATES

SUMMARY

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I. Introduction

The fertilizer requirements of a country are determined by several very different conditions. Prominent among these are:

(1) The amount and distribution of the annual rainfall.

(2) The physical texture and origin of the soil.

(3) The temperature, amount of sunshine, and duration of the growing season.

(4) The system of farming followed.

(5) The kinds of crops grown and sold from the farm.

Where the rainfall is always light and the total amount per annum is small, the nitrates which are formed by direct and indirect bacterial action in the soil are not subject to loss by leaching. On this account they have accumulated to an extent injurious to vegetation in parts of Colorado, Utah, and elsewhere in the arid and semi-arid regions of the West. What is true of nitrates is equally true of certain calcium, magnesium, potassium and sodium compounds. The excessive accumulations of the last named have given rise to the white alkali (sodium sulphate) and to the more greatly dreaded black alkali (sodium carbonate) of many western lands.

In the tropics, on the contrary, where the total rainfall is great and where several inches of rain may fall within a few hours, nitrates are likely to be leached out of the soil to a serious extent, especially if it is of a sandy character. In such circumstances potassium, sodium, calcium and magnesium salts are also lost to a considerable extent by leaching. It is, in fact, not uncommon in the tropics for the soil silicates to become so depleted of the basic ingredients and silica that laterite (a ferruginous aluminum hydroxide) is practically all that remains.

Because of the influence of rainfall, potash is quite generally required as a supplement to the soil supply in many sections of the East and South and even to some extent for certain crops as far west as Texas, Missouri and Wisconsin; and possibly, in the case of crops requiring much potash, even at more distant western points.

In general, siliceous, sandy soils are notably deficient in nitrogen, phosphoric acid and lime, and seriously tho often to a less extent in potash, and occasionally in magnesia. Soils of limestone origin are usually less in need of phosphoric acid than those derived from granite, siliceous conglomerates, sandstone or even from certain shales and slates. Muck and peat soils are usually seriously in need of potash and are deficient in phosphoric acid, because, whatever amounts of these ingredients may have been present in the vegetation from which they were formed, conditions have been most favorable to their subsequent loss by leaching. Clayey soils and to a less extent silt loam soils are often fairly well supplied with potash, unless they have been cropped heavily with plants which remove large amounts of it from the soil.

High temperature coupled with excessive rainfall is not only conducive to serious loss of the plant-food bases ordinarily present in soil silicates, but also to the rapid nitrification of ammonium salts and organic ammoniates, which necessitates the frequent renewal of the humus and the frequent use of liberal quantities of nitrogen in suitable combinations.

It is a notable fact that crops which grow and mature in a short time, early in the season before nitrification has become most active, as, for example, certain of the small grains, are much more in need of nitrogenous fertilizers than Indian corn, which grows practically throughout the entire season. But no system of farming is so destructive of soil humus or necessitates such liberal supplies of plant food as " truck " or market gardening, because the land is used continuously or almost continuously for hoed crops. Furthermore, the earliest truck soils are usually sandy and hence readily lose some of their plant food by leaching. Where the area under cultivation is ample, the occasional laying down of part of the land to grass, clover, alfalfa and similar crops, or the turning under of green crops will lessen the necessity for manure as a physical ameliorant, but will not lessen greatly the need for inorganic salts, particularly for potash and phosphoric acid. The turning under of leguminous crops which, in conjunction with a few non-legumes, have the capacity for assimilating and fixing atmospheric nitrogen by virtue of the bacteria which inhabit the nodules on their roots, will often add considerable nitrogen to the soil. It must be remembered, however, that they, like other plants, can and do utilize much of the combined nitrogen already available in the soil and that often, therefore, only a part of their nitrogen content represents actual fixation of the free nitrogen of the air.

A system of agriculture in which the culture of deep rooting crops like clover and alfalfa is practised, has an advantage over the continual growth of shallow rooting crops, such as the strawberry, for the reason that the deeper roots are able to draw some mineral foods from levels which are inaccessible to the other plants. It should be borne in mind that the plant is not dependent solely upon the plant food present in water-soluble form, but that the roots have the power of dissolving more or less plant food from the soil particles.

The selling of cereals or milk will rapidly deplete a farm of its available supply of phosphoric acid, whereas the raising of cattle and swine, and the sale of cream or butter instead of milk, will greatly conserve the supply of plant food. The greatest possible conservation of the native plant food of the soil is effected by the growing of legumes, in conjunction with the practice of animal husbandry, and by selling from the farm practically nothing but cream, butter and farm animals. And the cotton grower, if he were to have his cotton seed returned as cake after the extraction of the oil and fed on the farm, would be conducting his business essentially on the same economic plan as the farmer who sells chiefly cream or butter, for he would be selling from the farm but little plant food, and the farm manure would aid him materially in the maintenance of a good supply of humus and of the tilth of the soil. The farmer, who sells milk, hay, cereals, beets, turnips, and tobacco is following a plan which will lead to depletion unless suitable amounts of plant food are returned to the soil. The grower of cereals, when he sells his straw for the manufacture of paper or for other purposes instead of utilizing it on the farm, is hastening still further the time when plant food must be purchased in order to maintain maximum production.

II. NITROGEN

Can the use of nitrogenous fertilizers be curtailed without economic loss ? It is an accepted fact that a large amount of ammonia which escapes from farm manures might be saved if proper methods of handling and applying it were employed. No doubt also a much larger amount of atmospheric nitrogen would be fixed in our soils than at present if they were properly limed, for the Azotobacter which require no association with host plants multiply far more freely in limed soil and are able to fix much greater quantities of atmospheric nitrogen than in highly acid soils which are practically devoid of carbonate of lime. When one considers the fact that more than 200 million acres of the cultivated land in the United States are in serious need of liming, the significance of liming as a matter of national economy becomes apparent. The importance of the use of lime as a factor in nitrogen economy is further emphasized by the fact that there are hundreds of thousands of acres of land in the United States which cannot be made to produce successfully clover, alfalfa and certain leguminous or other nitrogen-fixing plants until they are properly limed. The great obstacle in the way of fixing more free atmospheric nitrogen by means of

Azotobacter and legumes is the difficulty of reaching every farmer whose land needs liming and of convincing him of the possibilities of profit from its use. Unfortunately many such farmers are unable to purchase the lime because of lack of resources, while their natural timidity restrains them from the venture of borrowing; and finally, if they could be brought to the point of using lime freely the railroads would be utterly unable at this time to deliver the 200 to 300 million tons of ground limestone or other forms of lime which should be used the coming spring.

For these various reasons there is little hope that the use of lime will immediately lessen the necessity and demand for nitrogenous fertilizers. In fact, when we consider that in 1914 we were using in the United States on our 478.5 million acres of tillable land only about 7 million tons of fertilizer as compared with the use of approximately the same amount by Germany on her 81.9 million acres, it will be seen that we have probably only begun to approach our actual requirements if our crop production is to be raised to its highest possible level. It has been stated by Professor Von Seelhorst of the University of Göttingen, Germany, that half of the increase in the German crops in the years just prior to the war was due to the greater use of fertilizers; Professors Schneidewind and Gerlach also attribute a very large part of the increase to the same cause; and it must not be forgotten that nitrogen constitutes a very important part of both the German and American fertilizer requirements.

The chief sources of nitrogen in commercial fertilizers are meat tankage from rendering establishments; cotton-seed meal; sulphate of ammonia, chiefly from by-product coke ovens; nitrate of soda from Chile; and calcium cyanamid of American manufacture. Dried blood, fish waste and various other waste nitrogenous materials are also employed, some of which, tho of low availability in their native state, are made highly available to plants by special chemical treatment in the factory.

The question of great national importance at this time is, Can we safely curtail or do without nitrogenous fertilizers? In the discussion of our national potash requirements it seems to be the prevailing opinion of our agricultural scientists that in the past much more potash has been used in certain parts of the country than has been necessary, but it is a significant fact that this opinion does not seem to be held as concerns the use of nitrogen in the cotton fields of the South nor in connection with the growth of truck and general crops from Maine to Florida in the East, nor is it generally held concerning the use of nitrogen in the fertilizers for seeding winter wheat and other winter and spring grains.

Unfortunately as concerns organic ammoniates, the supply in its relation to the requirements of the country is steadily decreasing and the situation in this respect is likely to grow steadily worse, for our cattle production is not keeping pace with our increase in population and if it did, still more nitrogenous products, which have heretofore served as fertilizers, would be required for feeding. In the transformation of feed into manure and its transference to the field, considerable nitrogen is always lost. The animal ammoniates such as meat scrap, fish waste and meat tankage are being used more and more as animal food, as the price of other feeding stuffs advances. The domestic demand for cotton-seed meal or cake for cattle feeding is increasing steadily, and as a matter of national economy it should increase until every pound is utilized in this country. Vast quantities of plant food might thus be kept at home instead of sending the meal or cake abroad to be fed to animals for the production of cheese, hides, milk sugar and other animal products which heretofore have been imported from Europe, Argentina and elsewhere.

The feasibility of the increase of our livestock and conservation of the plant food in our cotton seed is evident when one considers the vast areas of waste land in the North and especially in the South which are well adapted to the production of the roughage which must constitute the basal part of the animal ration. For the accomplishment of this purpose, the warfare against the southern cattle tick, the cause of Texas fever, must be continued until the entire South is free from this scourge. Hand in hand with this movement must go proper diversification of southern agriculture, not only in the ultimate interest of larger crops but also as a matter of ultimate national economy in transportation.

The idea of each section of the country producing only that which it can produce most profitably and then of exchanging products is fraught with fatal possibilities, as for example in seasons like the last when the corn in the corn belt was so seriously injured by frost that much of it molded in the bins, and when the potato crop of Aroostook County, Maine, was cut in half by blight. As a matter of national foresight, therefore, we must not put our eggs in one basket and as a consequence burden our overtaxed railroads with unnecessary transportation.

Even with the present extent of animal production and the existing demands for cattle foods, we are far from having adequate organic ammoniates to meet our present fertilizer requirements, and hence there can be no curtailment of their use unless far greater amounts of nitrates and ammonium salts can be made available.

As concerns nitrate of soda, the demand has kept steadily in advance of the possibility of supply because of the enormous requirements for the manufacture of munitions and of the difficulty in securing adequate shipment from Chile. This material is of special importance as a source of nitrogen for sugar beets, for truck crops which must be forced rapidly, also for potatoes, onions and other crops which are grown in cold climates. This is because the nitrogen in nitrates is in a form which can be taken and utilized by plants without undergoing bacterial transformation in the soil, whereas the greater part at least of the nitrogen in sulphate of ammonia must undergo nitrification before it becomes fully effective; most of that in organic ammoniates must undergo both ammonification and subsequent transformation into nitric acid and nitrates.

Another distinct advantage of nitrates such as nitrate of soda is that they are especially adapted to the spring top-dressing of grass, of winter cereals, and for periodic application for various crops which are grown on sandy soils.

In connection with the writer's earlier experiments with various nitrogenous fertilizers on a quite acid, upland, well-drained soil, it was found that while the efficiency of the nitrogen of nitrate of soda was normal or 100 per cent, the efficiency of the nitrogen in dried blood, one of the best of organic ammoniates, was only 45.5 per cent. Ammonium sulphate, instead of serving as an efficient fertilizer, was positively toxic. On the other hand, the efficiency of the nitrogen in dried blood, when used on properly limed soil, rose to 90 per cent and that of ammonium sulphate to 92 per cent. When one contemplates the fact that at least 200 million acres of land are being regularly tilled in the United States which are acid and in immediate need of lime, and that at least a considerable part of this land may be sufficiently acid to materially lessen the efficiency of the nitrogen in these other forms, the great advantage of an adequate supply of nitrates becomes most obvious. In addition to the advantage of nitrates just cited, mention should also be made of the fact that after the plant has removed and utilized the nitric acid which it carries, the residue of soda is changed into sodium carbonates or is added to the basic ingredients of the soil silicates, so that the ultimate effect is to lessen slightly the prevailing acidity of the soil.

In the manufacture of commercial fertilizers nitrates such as nitrate of soda are not only of value by way of supplying nitrogen in a form which the plant can utilize without delay, but also for the reason that the soda or basic part of the material can combine in the soil with the sulphuric acid of the ammonium sulphate and can combine with the nitric acid formed from organic ammoniates or can replace in the soil silicates other bases which may enter into such combination. The nitrate, therefore, not only serves as an insurance of efficient action of the nitrogen in the associated nitrogenous compounds, but it also aids in maintaining a soil reaction best suited to most agricultural plants, for it is only the exceptional agricultural plant that thrives better on a quite acid soil than on one which is only slightly acid, neutral or but slightly alkaline.

From what has preceded it is evident that the increase of our supply of nitrates, from our western arid plains if possible, or if not from Chile, is of great importance in connection with our national food problem.

Too much emphasis cannot be laid upon the importance of stimulating the production of ammonia from soft coal in this country until every possible beehive coke oven is replaced by a by-product oven in order that every pound of ammonia may be recovered. Such ammonia may be recovered as ammonium hydroxid or it may be utilized for refrigerating or be transformed into ammonium sulphate for fertilizer and other purposes. The latter compound is an excellent source of nitrogen for use in mixed fertilizers (with nitrates and organic ammoniates) because it stands between the two in its quickness of availability and also because the ammonia, unlike the nitrogen in nitrates, can enter into chemical combination with the soil silicates and thus be better safeguarded from loss by leaching until the plant requires it. Altho some of the ammonia may be utilized as such by many agricultural plants, most of it is transformed into nitric acid and nitrates before the plants actually use it.

III. Phosphoric Acid

By far the most important and generally deficient ingredient of fertilizers is phosphoric acid. The chief source of this plant food in the United States prior to 1870–80 was bone, much of which was ground and utilized in its raw state, or steamed and then ground. As a result of the discoveries made by Liebig and of the wide dissemination of the knowledge resulting from the work of Sir John B. Lawes and Dr. Gilbert of Rothamsted, England, the manufacture of bone into superphosphate by treatment with sulphuric acid was early undertaken in this country. As the knowledge of the increased availability and efficiency of superphosphate as compared with bone became widespread, the demand for superphosphate, just as in England, increased to such an extent that even the scouring of the old European battle fields and of the ends of the earth no longer furnished enough. The supply was increased for a time by the importation of guano from the islands of the Pacific and elsewhere; but soon the discovery of the South Carolina phosphates, followed by those of Florida, Tennessee and finally of the western states, has placed at the disposal of the American people enormous supplies of rock phosphate which by treatment with sulphuric acid have been found to be quite the equal of the superphosphate made from bone. Phosphoric acid has not been used to excess in American agriculture; on the contrary, the general cry of agricultural chemists, agronomists and of well informed farmers is that more superphosphate should be made available, especially in the Middle West, where fertilizers were looked upon askance so long as corn was the cheapest available fuel and wheat was sold for a song. Now, with corn and wheat at undreamed-of prices, everything is undergoing a change, and the farmers of the Middle West are becoming fully awake to the fact that, aside from instances of serious deficiencies of lime, phosphoric acid is, in general, the plant-food ingredient in which their soils are chiefly deficient, and that they can reap an enormous benefit from applying superphosphate. It is also true that when this superphosphate is used, the opportunity for the profitable use of more nitrogen and even sometimes of potash is greatly increased.

So great and urgent has become the demand for superphosphate that it can hardly be supplied. This is because it is difficult and costly to secure vessels for the transportation to the United States of the Spanish pyrites (iron sulphide) chiefly used in the manufacture of sulphuric acid, and our own supply of pyrites is still wholly inadequate. In order to meet the need the output of American sulphur has been greatly increased and the country has been searched from end to end for pyrites. This situation would not be so acute were it not for the fact that such an enormous amount of sulphuric acid is required for the manufacture of munitions that the expansion of existing acid plants and the addition of many new ones still fail to supply the full need.

IV. POTASH

The potash situation, altho not the most important from a national fertilizer standpoint, is nevertheless acute in special localities, and it is likely to become more so, unless the supply available for fertilizer manufacture is soon notably augmented at prices which the farmer can afford to pay. In view of the circumstance that our supply of potash for agricultural purposes has come in the past almost exclusively from Germany, and the consequent international significance of the potash problem, this phase of the fertilizer question calls for detailed consideration.

There is probably no agricultural question concerning which the present opinions of authorities are so divergent as that of the country's potash requirements for agricultural purposes. This is no doubt due in part to local points of view, arising from the fact that climatic conditions and the characteristics of the soils vary so widely. Further, there is perhaps a greater difference in the requirement for potash on the part of different plants than for nitrogen, phosphoric acid or any other plant food, unless it be lime. While the amount of potash required for tobacco, potatoes, onions, turnips, beets and certain other crops is great, others (wheat, for example) require but little of it on certain clay soils, especially if the straw is utilized and returned to the land in the form of manure.

Unfortunately no other element can more than partially replace potassium in the plant, for it is essential to the formation and translocation of starch and in the synthesis of other carbohydrates. It doubtless per-forms several other functions which for some plants can be partially, at least, replaced by sodium; altho under normal conditions and at prices existing before the war, it would not have been the part of wisdom to take the risk of loss in yield in the attempt to restrict the potash supply so much that soda could replace it to a practical extent.[1] Again, beets, turnips, radishes and doubtless many other plants will take up far more potash than is necessary to meet their minimum requirements, provided it is present in available form in the soil. In such cases if sodium salts are added to the soil, the plants will take up relatively less potash and more soda than otherwise, without depressing the yield. Sodium thus conserves the soil supply of potash and serves to satisfy a part of the luxury consumption (what the Germans call *Luxusconsum*), or requirement for total mineral ingredients in excess of the absolute minimum requirement of each — a surplus demand which might be satisfied equally well, to a considerable extent at least, with other mineral matter. Soda can doubtless take the place of some potash physiologically in the plant, since it forms soluble salts with certain organic acids which are produced in connection with the synthesis of the proteins.

The following statistical survey of the needs of the various states, which rests chiefly on inquiries made directly by the writer, will serve to show how much potash is required, and for what crops. In view of the importance of the subject and of the differences of opinion to which reference has already been made, presentation of the evidence in detail seems desirable.

Recent investigations by representatives of the United States Department of Agriculture and the Maine

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[1] In this connection it is interesting to note that potatoes are somewhat helped by common salt, sodium carbonate, and doubtless by sodium sulphate and other sodium salts, when the supply of potash is inadequate; yet no soda, or no more than traces, may be found in the potato tubers.

Agricultural Experiment Station have shown that already on the type of soil in Aroostook County, Maine, known as the Washburn loam, the potash supply for potatoes is becoming distinctly deficient. This is shown by a peculiar distorting, discoloring or bronzing, and in serious cases by a final blackening and dying of the plants. Fortunately, however, this type of soil is not of wide extent. On the chief soil type of the district, the Caribou loam, the potatoes have not as yet shown the striking characteristics of serious "potash hunger." Nevertheless, according to Director Woods of the Maine Agricultural Experiment Station, the farmers of the state generally will need all the potash they can hope to get at present, and he adds: "There is no question but what on potatoes and root crops in general potash pays agriculturally and financially in this state."

In New Hampshire the Agricultural Experiment Station reports that the relatively heavy clay soils of the state do not require potash for the production of grass, or at least that a dollar expended for potash on the basis of former prices has yielded only a dollar in return. Nevertheless, experiments with grass conducted under the direction of the writer in the southern part of that state, on soils of miscellaneous character, have shown that the use of potash was profitable at the prices which prevailed before the war. Such being the case, there is without doubt a considerably greater need of potash, particularly for potatoes and other vegetables, and for many of the miscellaneous farm crops. Director Brooks of the Agricultural Experiment Station of Massachusetts says that he is "by no means convinced that the use of potash in our agriculture has been excessive." Director J. G. Lipman of the Agricultural Experiment Station of New Jersey is of the opinion that the actual needs of that state for 1918 would be reasonably met by a supply equivalent to 5,000 tons of muriate of potash. Assuming that New Jersey will require 129,800 tons of fertilizer in 1918, which was the amount used in 1916, the average percentage of potash which should be present in the fertilizers for that state would therefore be 1.93. The most reliable estimates obtainable from other sources for the New England states, New York, Pennsylvania, New Jersey, Delaware, and Maryland place the average required amount of potash at approximately 2 per cent. Using the most authoritative estimates of the fertilizers sold in 1916 as a basis, these states would, therefore, need for the manufacture of the required amount of fertilizer (1,584,255 tons), a total amount of potash equivalent to 63,370 tons of muriate of potash.

According to Dr. Oswald Schreiner and others connected with the United States Department of Agriculture, a considerable part of the early dying of vines in 1917 in the potato districts around Norfolk, Virginia, may have been caused by a deficiency of potash. Early in July, 1917, the writer visited the Norfolk potato region with Dr. Schreiner, but at that time, while there was evidence of serious injury having been caused by something, there were but few positive evidences of potash hunger observable on the potato leaves. This was, however, doubtless due to the lateness of the season and to the fact that the vines on the worst fields were dead and in many cases the crops had been dug. It is quite possible that the conditions which arose, even if caused directly or indirectly by a deficiency of potash, were greatly exaggerated by highly unfavorable moisture and temperature conditions during much of the early part of the growing season, and that they may not be as serious another season. In any event, it is clear there is present or approaching need of much more potash for the tide-water and trucking regions of Virginia than has been available to the farmers for the past two years. It is stated by Director Johnson of the Virginia Truck Experiment Station that the two counties, Northampton and Accomac, use about 55,000 tons of fertilizer annually. That amount, he says, should contain 5 per cent of potash, but recently it has not contained an average of over 2 per cent. On a 5 per cent basis, the equivalent of 5,500 tons of muriate of potash would be required for those two counties. This would leave, on the basis of the sales of 1916, a balance of 314,520 tons which, on the conservative estimate of 2 per cent as an average potash content of the fertilizer for the remainder of the state, would require the equivalent of 18,081 tons of muriate of potash — or a total requirement for the whole state of 23,581 tons. There was actually used in Virginia in 1917 only the equivalent of 4,500 tons of muriate of potash.

In a recent letter from Professor T. E. Keitt of Clemson College, South Carolina, he speaks of the potash requirement of that state as follows: "I will say that our experimental work does not justify its use for corn or small grains. Under the present conditions it is not advisable to use potash on the heavy clay phases of the piedmont regions for cotton, but on the sandy phases of the southern part of this state potash gives splendid results applied to cotton. Under present conditions I shall recommend the use of only 2 or 3 per cent, but if we had cheap potash I would prefer to use as high as 6 per cent on the section contiguous to our Coast Experiment Station for cotton." The same writer considers potash valuable in that state for the truck crops, and expresses the opinion that about one-half of the total fertilizer tonnage used in the state should contain from 2 to 3 per cent of potash if possible. On the basis of 2.5 per cent of potash, and assuming the same amount of fertilizer to be needed in South Carolina in 1918 as in the fiscal year ended June 30, 1917 (850,790 tons), there would be required the equivalent of 42,539 tons of muriate of potash. Another highly authoritative statement places the average requirement on a 3½ per cent basis. On this basis, assuming the same tonnage, the equivalent of 59,555 tons of muriate of potash are needed in 1918. In North Carolina, according to Director B. W. Kilgore of the State Agricultural Experiment Station, more potash was used on many soils before the war than was necessary for economic crop production. The best estimates available place the need for that state at the equivalent of about 30,000 to 40,000 tons of muriate of potash. This represents an average of a little over 2 per cent of potash in a minimum of 800,000 tons of fertilizer which should be used, as compared with the 650,000 tons which were used in 1916.

In Florida, prior to the serious shortage, the average amount of potash in the commercial fertilizers used ranged from 6 to 7.5 per cent, whereas in 1916 it was only 3.28 per cent. It is stated by Director P. H. Rolfs of the State Experiment Station that the average percentage in 1918 should be greater than in 1916. Assuming the same volume of sales in Florida in 1918 as in 1916 (the figures for 1917 are not yet at hand), which is probably far below the actual tonnage which will be sold, there would be required as a minimum in 1918 the equivalent of 20,338 tons of muriate of potash.

In Georgia the sandy soils of the coastal plains require considerable potash, but the piedmont and mountain soils require much less. Professor C. K. McClelland of the Georgia Agricultural Experiment Station estimates that in 1918 there should be supplied in the fertilizers in southern Georgia an equivalent of about 72,000 tons of muriate of potash, in those for middle Georgia about 24,000 tons and in those for the northern part of the state about 6,000 tons — or a total of 102,000 tons for the entire state. Assuming the view of Professor J. N. Harper to be correct, namely that Georgia should have an average of 3 per cent of potash, there would be required, on the basis of the fertilizer sales in 1916 (741,347 tons), the equivalent of 44,481 tons of muriate of potash. The actual requirement is likely to be much greater in 1918 than in 1916, which would bring these estimates much nearer together.

Employing Professor Harper's estimate for Alabama, there would be required in that state, if the tonnage of fertilizer were the same as in 1916 (206,000 tons), the equivalent of 8,200 tons of muriate of potash.

The views of Professor W. F. Hand of Mississippi are in agreement with practically all authorities in the South to the effect that much more potash was used there before the war than was necessary. This, however, has proved a blessing in disguise, for but little of the amount used was lost by leaching and it is helping materially in the present crisis. Assuming Professor Hand's estimate to be correct, approximately 60,000 tons of complete fertilizer will be needed in Mississippi in 1918. This he estimates should contain 2 per cent of potash, which would necessitate the use of the equivalent of 2,400 tons of muriate of potash. Professor Hand does not attribute the short cotton crop of the last three years to a deficiency of potash, which would be likely to give rise to cotton blight; he accounts for it rather by the activities of the cotton boll weevil.

A report from Director W. R. Dodson of the Louisiana Agricultural Experiment Station is to the effect that potash is practically not required in his state, excepting in the sections where strawberries and truck crops are grown. He estimates a probable consumption of only 300 to 400 tons of fertilizer containing 2 to 4 per cent. Assuming the maximum tonnage, there would be required on a basis of 3 per cent of potash only the equivalent of 24 tons of muriate of potash.

In writing of Tennessee, Professor C. A. Mooers says that "by constant cropping and the removal of crops, without the return of any fertilizer materials containing potash, it is easily possible to reduce the potash supply on average Tennessee soils to such an extent as to interfere seriously with the production of hay crops. . . . As a rule the potash supply is fairly good throughout the state except for certain areas, in particular the 'barrens' of the Highland Rim and the sandy loams of the Cumberland Plateau." It is the general practice to recommend some potash in fertilizers for trucking crops in practically all parts of the state. By following the good methods of farming in vogue in Lancaster County, Professor Mooers believes that the use of potash would be unnecessary "even on the poorest soils of the state." He nevertheless advocates the use of some potash for potatoes and for hay crops on one-fifth of the area of the state. The total quantity of fertilizer sold in the state in 1916 was 91,128 tons. Assuming that 10,000 tons of this should contain 4 per cent of potash, the percentage suggested by Professor Mooers for hay and potato crops, the equivalent of 8,000 tons of muriate of potash would provide for the needs of the state.

Acting Director Peter of the Kentucky Agricultural Experiment Station says that their experiments "show that Kentucky does not need potash for field crops generally." It has been supposed that truck crops needed it, but the results of experiments in 1917 show that, for a brief time at least, the growers "can get along very well on a limited supply." In 1917 enough fertilizer tags were sold in Kentucky "to tag about 40,000 tons of fertilizer containing 1 per cent of potash." Assuming as a rough approximation a need of 10,000 tons of goods containing that amount of potash, the requirement for 1918 would be equal to the equivalent of 2,000 tons of muriate of potash.

What Professor Mooers has suggested as a possibility if good methods of agriculture were practised in Tennessee, is supported by the views of Professor C. G. Hopkins of Illinois who holds that potash is not required in that state where live-stock farming is practised and the manure is returned to the land. On certain soils Professor Hopkins states that "at least temporary use of commercial potash salts is desirable and profitable at pre-war prices for potash. These are the peaty swamp lands found in very limited areas widely scattered over northern Illinois, and the much more common poor prairie lands of southern Illinois." He asserts, however, that potash is not needed and is unprofitable even at pre-war prices on either type of soil where the farm manure which can be produced is returned to the land.

The situation in Ohio is most encouraging according to Director Charles E. Thorne of the State Agricultural Experiment Station, for he writes: "I would say that the investigations of this Station indicate that if Ohio farmers would carefully save and properly use their farmyard manure, they would not need to purchase any potash so long as it remains at present prices. My opinion, therefore, is that the actual agricultural potash requirement of our state at present is nil." This conclusion is based on a condition which cannot be brought about at once and it may be questioned if Director Thorne has not overlooked some important special crops in arriving at his sweeping conclusion.

There are large areas of land in Indiana which respond profitably to the use of potash at the normal prices existing before the war. According to Professor A. T. Wiancko, there are in the state about 500,000 acres of black soils which are deficient in potash, including mucks, peaty sands and black sandy loams; half of this area cannot be farmed profitably without the use of potash. In addition there are also considerable areas of " bogus " soil which will produce practically nothing without potash. Professor Wiancko says: " Counting 10 pounds of potash to the acre, the half million acres would require an equivalent of 5,000 tons of muriate of potash." In addition to this deficiency " there are, in the southern part of the state, at least two million acres of silt loam and so-called ' clay ' lands that have been badly farmed for many years." This area he says " will respond to potash fertilization even tho there are abundant potash supplies in the soil." It is believed, however, that at the present prices for potash it may be more profitable to do without it. Before the war the equivalent of about 20,000 tons of muriate of potash were used in the fertilizers in the state. Professor Wiancko points out, however, that many farmers should then have used it who used none and others should have used more than they did. For the ordinary clay soils where crop residues are properly conserved and a good system of manuring and fertilizing is in vogue, he asserts that potash is unnecessary.

Professor Patten of the Michigan Agricultural Experiment Station, states that potash appears to be unnecessary "on a large percentage of the soils in this state. On the muck soils and many of the sandy soils, especially where potatoes are grown, potash is more or less of a necessity still." He is of the opinion that if the fertilizers containing potash were wisely distributed, the equivalent of 1,500 to 2,000 tons of muriate of potash would meet the needs of Michigan in 1918.

The lands of northern Missouri are not generally much in need of potash is the report of Professor M. F. Miller. Potash yields some returns even there, but it is not being recommended now because of the high price. The sandy and gravelly soils of southern Missouri respond far more readily to potash than those in the northern section of the state. On the basis of a consumption of about 70,000 tons of fertilizer in 1917, Professor Miller estimates that the minimum requirement would be met if the equivalent of 700 tons of muriate of potash were available for use in the state in 1918. As regards the Southwest, at present New Mexico, Arizona, and Oklahoma do not appear to require potash. It is held by Professor Fraps of Texas that their ordinary corn and cotton fertilizer should contain only nitrogen and phosphoric acid. According to his estimate the equivalent of 600 tons of muriate of potash would meet the needs of Texas in 1918.

In Nebraska, according to Professor Fred W. Upson, the soils of the state " are generally abundantly supplied with potash and what few experiments have been carried out show that potash does not bring returns." The estimated sale of fertilizers in Nebraska in 1916 amounted to only 500 tons. The soils of Kansas also generally appear to yield enough potash for crops, says Professor R. I. Throckmorton, provided the " farmers keep up the organic content of our soils." He calls attention, however, to the possibility of the need of potash on the sandy types of soils which are devoted to potato culture. Assuming that the amount of fertilizer used in Kansas in 1918 should be the same as it was in 1916 (7,940 tons) and that one-fourth of this should be used for potatoes and contain 3 per cent of potash, the equivalent of 119 tons of muriate of potash would be required for the entire state.

The estimated total sale of fertilizer in Wisconsin in 1916 was only 5,000 tons, but doubtless the amount was much greater in 1917. The writer had not received any official estimate from Wisconsin of the potash requirement of the state when this article went to press and is therefore dependent upon his own coöperative fertilizer experiments, conducted there for the past three years, for an estimate. It is doubtless true that on the better soils where a good system of animal husbandry is practised, there is little or no present need of potash for ordinary field crops. Many of the reclaimed peat or muck soils, however, unquestionably need it as much as the similar soils of Illinois and Indiana. It is probable also that approximately 50 per cent of the sandy loam potato soils of the state need more or less potash, for an average of a large number of tests made in 1917 under the writer's direction shows that potash to the extent of about 40 pounds (equal to 80 pounds of muriate of potash) to the acre, in addition to liberal applications of nitrogen and available phosphoric acid, yielded approximately 100 per cent on the investment even with potatoes and potash at the present prevailing prices. There is indirect evidence also that some of the more sandy tobacco soils will respond favorably to potash if it is used in conjunction with proper proportions of other plant-food ingredients. Assuming that only one-half of the potato acreage of the state is represented by the somewhat sandy types of soil and that only half of that acreage would respond to potash to the degree mentioned above, and further assuming that only 30 pounds of potash are applied to the acre, there should be used in Wisconsin in 1918 an amount of potash equivalent to 2,175 tons of muriate of potash.

In Minnesota about 280,000 acres of potatoes are grown in comparison with 290,000 in Wisconsin. According to Professor F. J. Alway of the Minnesota Experiment Station, a very large acreage of land in the central part of this state is largely a fine sand or sandy loam. "No fertilizer experiments have been conducted on this except at Grand Rapids and there only in the use of manure in combination with different forms of phosphate." He also states that "experimental fields on the sandy lands in the counties immediately north of the Twin Cities are urgently needed." In the autumn of 1917, the writer visited certain of these sandy potato regions for the purpose of comparing the conditions with those in Wisconsin, and aside from the somewhat less rainfall in Minnesota the conditions are so similar that there is great likelihood that a considerable need of potash actually exists, provided the necessary supply of nitrogen and particularly of available phosphoric acid is used to supplement it properly. This seems probable notwithstanding the rather high total potash content of the soils, for in the case of potatoes especially it is important that there be a liberal supply of potash in readily available form.

It remains to be determined to what extent potash and other fertilizer ingredients may be needed in Iowa but, as has been said of Wisconsin (and the same might also have been stated in regard to Minnesota), doubtless on the better lands where animal husbandry is coupled with a rational system of farming, there is at present little or no need of potash. In some parts of Iowa fertilizers already give good returns but their use is as yet small; in 1916 it reached a total volume of but 5,000 tons.

There seems to be no evidence of need of potash in Colorado, Idaho, Montana, Nevada, North Dakota, South Dakota, and Wyoming, excepting in a restricted way in certain localities for greenhouse and truck crops, altho it is stated by Professor J. G. Hutton that phosphatic fertilizers are becoming necessary and profitable in some parts of South Dakota.

In southern Oregon, according to Professor H. V. Tartar, sulphate of potash was found helpful to alfalfa but muriate of potash was not. Other facts lead to the conclusion that it was the sulphur and not the potash which was needed, and the evidence to date does not point to any imperative need of potash in that state. What is true of Oregon is also doubtless true of Washington.

As concerns California, Professor John S. Burd of the State Agricultural Experiment Station at Berkeley says, " I have never heard of a single instance in which the use of potash in this state has ever been definitely demonstrated to have produced increased crops." The writer is unable to say at this time whether this also represents the views of the experts in the southern part of the state where citrus culture is of especial importance.

No official estimates have yet reached the writer concerning the potash needs of Arkansas and West Virginia but, assuming that an average content of 1 per cent is desirable, the amount of potash required, based on the sales of fertilizer in 1916, would be equivalent to 2,192 tons of muriate of potash for the present year.

A summing up of the need for potash in the several states, using the minimum statement or the average in the cases where the estimates of different authorities were divergent, shows that, if available, there should be used for agricultural purposes in the United States in 1918 at least 147,243 tons of actual potash (potassium oxide) equivalent to 294,486 tons of muriate of potash or about 736,215 tons of the crude potash salts now being produced from the Nebraska lakes.

The annual importations of potash for agricultural purposes prior to the war were about 226,000 tons of actual potash in the form of German potash salts, which were equivalent to about 452,000 tons of muriate of potash. It appears, therefore, from the figures given above that the estimated minimum requirement of potash for agricultural purposes in this country in 1918 is much more than half the annual consumption for such purposes prior to the war. It should, however, be borne in mind that for some states, notably Ohio, the estimated amount of potash required would have been greatly increased had those making the estimates been influenced not by present prices but by what the use of potash might accomplish in increasing crop production.

In contrast to this large agricultural requirement for potash in 1918, it should be pointed out that on the basis of our total potash production of the first six months of 1917 for all technical and agricultural purposes the equivalent of muriate of potash produced was but 56,092 tons for the year. Taking into account the probable rate of increase for the last six months it is doubtful if the total production for the entire year was much in excess of 60,000 tons. In other words the output was only about 20 per cent of the requirement for 1918 for agricultural purposes alone. These figures are sufficient to show that every effort should be made to increase our potash output to the utmost or there will be a serious falling off in crops in the near future.

Consider now the potential sources of supply. It is stated that there is in Searles Lake, California, enough potash, if ample means for recovering and purifying it were provided, to supply the needs of the country for forty years. A considerable amount is also available elsewhere from salt lakes and brines. If all of the potash liberated in the flue dust in connection with the cement industry were saved, it would amount to approximately 87,000 tons of actual potash or the equivalent of 174,000 tons of muriate of potash per annum; and a further amount might be recovered from blast furnaces. The giant kelp of the Pacific coast, alunite, feldspar, leucite, potassic silicates accumulated as waste in past mining operations, beet and cane sugar wastes, distillers' wastes, wool washings, tobacco waste and many other incidental sources of potash exist, which should be utilized in so far as it is economically possible. It is therefore true that we have many undeveloped possibilities of a future potash supply fully adequate for our national needs. But it is obvious that no one of these offers hope of furnishing any considerable amount at prices which will permit of serious competition with German muriate of potash (containing 50 per cent of potash) which can be landed in this country at $12 to $15 a ton and still yield a living profit to the producers. The only present hope for an adequate and sufficiently cheap supply of potash salts to fully meet German competition rests on the possibility of the discovery of great deposits of crystalline potash salts in this country, similar to those of Central Germany, Alsace-Lorraine, Galicia, and those claimed to have been discovered in Spain and Abyssinia. The prospect of discovering such deposits in the United States by chance borings is too slight to attract private capital. The undertaking is one which the federal government could and ought to promote.

V. CONCLUSION

In conclusion it should be stated that the country is facing the greatest shortage of organic ammoniates ever known. Considerable quantities of these are essential in the manufacture of fertilizers in order to keep the goods from lumping and hardening and to maintain them in such perfect mechanical condition that when the farmer is ready to use them they will flow freely through the various machines used in their application. Some fertilizer manufacturers who produce large amounts of organic ammoniates and hence use more than they otherwise would, might substitute for a part of them nitrate of soda, or sulphate of ammonia, or both. But at present these are unobtainable in sufficient quantities to meet the various requirements of the country.

Were it not for the enormous demand for sulphuric acid for war purposes and for the unusual cost for labor and transportation there would be at present an unlimited supply of superphosphate at relatively low prices, but under existing circumstances the prices are necessarily high and it is difficult for manufacturers to meet the urgent demand for it.

The withdrawal of the fertilizer supply of the country for a single year would cut the cotton crop of the South nearly in half. It would be a fatal blow to the farmers and to crop production in the East from Maine to Florida. It would greatly reduce the crop production of Indiana, Ohio, Michigan and other important agricultural states. It would in fact be nothing short of a national calamity.

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